Clarifying Harmful Interference Will Facilitate Wireless Innovation

A WHITE PAPER

By

IEEE-USA's Committee on Communications Policy

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Executive Summary

In recent years, many of the spectrum policy controversies in the United States have dealt with the basic issue of whether a proposed technology or service will cause "harmful interference" to existing spectrum users. Resolving these issues has typically taken several years in an era where technology is moving at "Internet speed." As the Federal Communications Commission (FCC) discussed in its Wireless Innovation Inquiry, the delays and lack of transparency associated with making go/no go determinations on harmful interference may be discouraging private investment in the development of innovative wireless technology.

This White Paper reviews the background of what is harmful interference and suggests incremental ways in which the two spectrum management agencies in the United States, the FCC and the National Telecommunications and Information Administration (NTIA), could clarify the definition by giving guidance on the sub-problems associated with harmful interference determinations. Changing the definition is probably impractical, due to the long list of precedents over decades that have been built on the current definition, even though it is not established by statute.

The White Paper also suggests that establishing timeliness goals similar to those voluntarily created by the FCC for equally complex and voluminous merger and acquisition reviews could also address the disincentives for private capital formation in the wireless technology area. Such timeliness goals could create a more "level playing field," with respect to other technical areas concerning private funding of technical development.

Introduction

The IEEE has a deep understanding of the reasons why some regulation is required in selected technologies that our membership invents and manufactures for the world-at-large. One of these reasons is the important technology of wireless communications.

Both international regulation and U.S. domestic regulation often talk about the concept of "harmful interference" in the context of wireless, as it often plays a key role in determining whether and under what terms a new technology or service is permitted. While introducing new wireless technology is important, the rights of incumbent wireless (or "spectrum") users are important as well.

<u>Both</u> regulatory certainty for incumbent users of wireless <u>and</u> flexibility to accommodate new innovative products and services for the public good are very important goals. But for various reasons, innovation in wireless technology often can put these two goals in conflict.

This fundamental conflict between interests of incumbents and innovators explains the difficulty regulators often have in devising a regime in a way that pleases all parties involved to address the overall public interest. However, the national importance of balancing these goals in our information age society and economy is a vital one. In fact, no matter how difficult the solution, one must be found—if for no other reason than supporting a nation's economic competitive advantage.

The tool usually used in in the U.S. spectrum regulation system in pursuing the important goal of balancing incumbent uses and innovation is the definition of *harmful interference* —a concept regulators have used as a means to measure harms to a spectrum user, and the service it provides.

While it is likely an unachievable goal to precisely "define" harmful interference, progress in clarifying what constitutes harmful interference will be helpful for both spectrum incumbents and wireless innovators by reducing present regulatory uncertainties. The harmful interference test for new services is embedded in decades of FCC decisions. The term is mentioned eight times in the *Communications*

Act[1], and with four more new references added in the recently enacted amendments to the Act in P.L. 112-96, yet it is never defined in legislation.

In classic wireless regulation, such as was in place in the United States prior to the mid-1970s, almost all innovative technologies needed positive regulatory action before they could be used in operational systems. Evolutionary changes to existing international spectrum regulation began in the aftermath of the 1912 *Titanic* disaster, and the formal regulation of radio in the United States began in the 1920s. The basic prescriptive regulation of wireless technology was introduced when relatively little spectrum was available for commercial operations, due to lack of technology, and therefore a poor ability to use it.

At the time the new FCC started down the path of detailed prescriptive regulation in 1935 during the New Deal, there was greater public support for the role of government regulation than is common today. It was also simple for the FCC to propose and adopt rules under its original legislation and the simple system of administrative law that existed at that time. Furthermore, the FCC could adopt "guidance," like its former *Standards of Good Engineering Practice,*[2] that had the impact of regulations—without even formal approval by the Commission.

The end of World War II changed the foundations of this system in both the technical and legal sense. The military technology advances during the war opened up higher and higher frequency bands and set in motion a movement that now has FCC rule provisions as high as 94 GHz and commercial production systems as high as 85 GHz. The following explosion in wireless technology resulted in a myriad of technology choices in modulation, channel access technology—other innovations that are a foundation of much that happens in wireless technology today. The expectation of ubiquitous wireless services as a part of everyday life became common, greatly increasing the demand for information to be delivered over wireless channels.

Finally, the "information age" resulted in a much faster rate of change of both technology and consumer demand for services, moving at "Internet speed."

At the same time demand and technology were accelerating, the aftermath of the New Deal and the partisan changes in Washington resulted in the *1946 Administrative Procedure Act/APA,*[3] that brought formal checks and balances to administrative regulation in the federal government by requiring notice and comment in rule makings, and formalizing the process of court review of agency actions. Court decisions of the next two decades clarified what *notice and comment* and *arbitrary and capricious*[4] meant in practice. The net result of the APA, and its growing case law, was that the ability of the FCC in the 1930s to readily update its wireless rules slowed significantly—just as the need to update them increased tremendously, due to movement to ever higher frequencies, expanding technological options, and expanding consumer demand for wireless services.

Currently, the general trend in wireless technical regulation in the United States has been for deregulation. This White Paper does not deal with changing this trend, rather it suggests that wireless regulations related to new types of wireless technologies and systems should be more transparent and clear, and should resolve in a more timely way policy determinations that may block innovation—or conversely enable new technologies to come to market in a more timely way.

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1 47 USC 302(a), 303(y)(2), 337, 354, 922, 923, 1100, 2511

2 FCC, *Standards of Good Engineering practice Concerning Broadcast Stations*, 1939 (http://www.hatdaw.com/papers/Standards_of_good_engineering.PDF); *FCC v. WJR, The Goodwill Station, Inc.,* 337 U.S. 265 (1949)

3 5 U.S.C. 553

4 5 U.S.C. 702

Wireless Technical Innovation and Regulation

The early 20th century model of detailed regulation of wireless technology, and a prescriptive approach towards new technology, became increasingly inappropriate in the second half of the century. While the certainty resulting from permitting only enumerated technologies; slow adoption of new ones helped established industry players make long-term research, development and manufacturing plans. It was also a serious disincentive for new entrants to the field since new technology could only be implemented after a multi-year regulatory battle, in which established players and their allies would subject the new technology to detailed public review and criticism.

In the period preceding spectrum auctions and the accompanying spectrum technical deregulation in the 1990s, at times it appeared that the major wireless incumbents, both licensees and equipment manufacturers, used their "inside track position" at the FCC to delay innovative technologies that they did not control. This way, they could both minimize the threat of potential new competitors, as well as ensure that they could fully amortize the cost of new product development and new equipment, before they became obsolete.

Indeed, the perception of excessive regulatory delay at the FCC was the very reason for the adoption of 47 USC 157(b)[5] in 1983, which attempted to set a one-year time limit on deliberations of new technologies and services for the FCC. Unfortunately, the language of §157(b) was not clear enough to have any real impact, and the hard, one-year limit was probably unrealistic. In any case, §157 has had nearly no real impact in the nearly 30 years since it was first passed. §157 might even have been worse than a total failure, in that it may have given unreasonable expectations to innovators and entrepreneurs during this period to launch hopeless attempts to get questions of new technology resolved in a timely way. Such repeated failures may well have made capital for innovative technologies harder to obtain rather than easier.

The FCC movement toward technical deregulation of wireless technology and "technical flexibility" begun in the late 1970s was an attempt to get out of the need for case-by-case adjudication of new wireless technologies. However, at its core was the need to make some general findings about the interference potential of new technologies, as the previous new technology rulemakings were really *ad hoc* determinations of this issue. A general threshold for interference potential is desirable to achieve complete transparency for new technology, as well as protect incumbents. In reality, this goal is a near impossibility, particularly in the present policy deliberation structure.

Transparency

Transparency in regulation deals with both the formulation of regulations and their implementation. Regulations should be adopted in an open manner, in which affected parties can comment on them and these comments are addressed in the final decision-making. Regulation transparency is the heart of the *U.S. Administrative Procedures Act*. Further, the regulations should be clear enough that affected parties understand what they mean, and see the factors that affect how they will be interpreted in new circumstances. The World Bank has written that *"(t)o reassure stakeholders, regulatory decisions must be made according to established rules methodologies, and processes. That calls for setting out in*

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5 "The Commission shall determine whether any new technology or service proposed in a petition or application is in the public interest, within one year after such petition or application is filed. If the Commission initiates its own proceeding for a new technology or service, such proceeding shall be completed within 12 months after it is initiated."

openly available regulatory documents, in as much detail as possible, the factors feeding into the regulator's decision."[6]

The FCC's *Best Practices for National Spectrum Management*[7] includes the following points:

- Promoting **transparent**, fair, economically efficient, and effective spectrum management policies, i.e., regulating the efficient and adequate use of the spectrum, taking into due account the need to avoid harmful interference, and the possibility of imposing technical restrictions to safeguard the public interest (emphasis added)
- Making public, wherever practicable, national frequency allocation plans and frequency assignment data to encourage openness; and to facilitate development of new radio systems, i.e., carrying out public consultations on proposed changes to national frequency allocation plans, and on spectrum management decisions likely to affect service providers, to allow interested parties to participate in the decision-making process
- Maintaining a stable decision-making process that permits consideration of the public interest in managing the radio frequency spectrum; i.e., providing legal certainty by having fair and transparent processes for granting licenses for the use of spectrum, using competitive mechanisms, when necessary
- Adopting decisions that are technologically neutral and allow for evolution to new radio applications
- Facilitating timely introduction of appropriate new applications and technology, while protecting existing services from harmful interference including, when appropriate, the provision of a mechanism to allow compensation for systems that must redeploy for new spectrum needs
- Considering effective policies to mitigate harm to users of existing services when reallocating spectrum

Transparency is a key part of U.S. spectrum management, as well as a U.S. recommendation for other countries.

Harmful Interference

The FCC has a longstanding tradition to allow new wireless technologies, if they do not cause harmful interference to other spectrum users. In the U.S. common law system, the decades of use of harm interference as a protection criterion has created legal precedents that are not easily replaced by another criteria. As was mentioned previously, "harmful interference" is *referenced* multiple times in legislation—but it is not *defined* there. The only explicit definition is the same one used in the ITU Radio Regulations, incorporated verbatim into the FCC Rules[8] and the NTIA Red Book. This definition states that harmful interference is *"(i)nterference which endangers the functioning of a radionavigation service*

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6 World Bank, Public-Private Infrastructure Advisory Facility, *How to improve regulatory transparency*, June 2006 (http://www.ppiaf.org/ppiaf/sites/ppiaf.org/files/publication/Gridlines-11-How%20to%20Improve%20Regularotry%20Transparency%20-%20LBertolini.pdf)

7 http://transition.fcc.gov/ib/sand/irb/bestpractices.html

8 47 C.F.R. 2.1

or of other safety services, or seriously degrades, obstructs, or repeatedly interrupts a radiocommunication service operating in accordance with [the ITU] Radio Regulations."

This definition implicitly contains two subcases. First, for the case of *"a radionavigation service*[9] *or of other safety services*," harmful interference is something that *"endangers the functioning"* of the service. For the cases of other radio services, harmful interference is something that *"seriously degrades, obstructs, or repeatedly interrupts"* the service.

While International Telecommunication Union (ITU) has used the related concept of "tolerable interference" in interservice spectrum sharing deliberations, the criteria consistently used in both U.S. legislation, and decades of FCC precedents, is *"harmful interference,"* which continues to be poorly defined and adjudicated, in a time-consuming process that has major transparency problems.

As part of President G. W. Bush's *Spectrum Policy Initiative*, begun in May 2003 to *"promote the development and implementation of a United States spectrum policy for the 21st century,"* NTIA attempted to identify *"interference protection criteria"/IPC for wireless systems."* This study was intended to be a two-part, with the first part surveying national and international precedents in harmful interference. In the second part, NTIA intended to *"review the relevant federal government policies and practices regarding IPC; and recommend regulatory and technical refinements that may improve IPC application's scope, utility, clarity, or effectiveness."*[10]

In the six years since the Phase I Report, NTIA has never produced the Phase II Report., probably because it underestimated the complexity of this issue and its implications.

Any FCC or NTIA statement attempting to clarify harmful interference is made difficult by the fact that many key players, whose participation is needed in the usual consensus development, may see no advantage to moving away from the *status quo*.

The problem of ambiguity and lengthy regulatory determinations of what is harmful interference directly impacts innovators more than it affects incumbents who might see such delays as advantageous. However, uncertainties might also impact long-term capital formation for incumbents, should investors performing due diligence observe transparency problems, with respect to protecting their investment, or understanding the total risk involved.

In the FCC's *Wireless Innovation NOI*, the Commission recognized the importance of clarifying harmful interference by saying:

> *"Spectrum allocations and access often hinge on controlling interference between new services and incumbent services, as do licensing and service rules, to some extent. The resolution of disputes about potential or actual interference in rulemakings can pose a major impediment to the introduction of new services, devices and technologies, either as a result of long delays in the establishment of service rules, or the imposition of onerous and perhaps unachievable technical standards.*
>
> *What are the best ways to balance the interference protection rights of incumbents against the opportunities for access to spectrum, and how do interference protection considerations affect innovation? Radio services are generally afforded protection from "harmful interference" on either a primary or secondary basis depending upon their status in the Table of Frequency Allocations. The trend of more radio services and devices seeking to use extremely weak signals and mobility*

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9 Radionavigation is, in turn, defined as "*Radio determination used for the purposes of navigation, including obstruction warning." "Safety service"* is defined as *"(a)ny radiocommunication service used permanently or temporarily for the safeguarding of human life and property".* - 47 C.F.R. 2.1

10 NTIA, *INTERFERENCE PROTECTION CRITERIA Phase 1 - Compilation from Existing Sources,* NTIA Report 05-432, October 2005, (http://www.ntia.doc.gov/osmhome/reports/ntia05-432/IPC_Phase_1_Report.pdf)

bringing products in closer proximity to each other is making the risk of interference a more acute problem. A challenge for the Commission is that application of these criteria often devolves to a case-by-case interpretation of conflicting data. What criteria should be specified and how would they be quantified? …The viability of spectrum access for new radio services often centers on whether the new service may cause harmful interference to incumbent services. This can lead to delays through protracted rule making proceedings that can create uncertainty and discourage investment. [11] (Footnotes omitted)

In the regulatory *status quo,* the FCC makes determinations of harmful interference from a potential

new system based on the cryptic definition in its Rules, and on vague past precedents. In cases involving possible interference to federal government systems, NTIA provides input to the FCC, that under existing *ex parte,* rules need only be made public just prior to any FCC decision.[12] In general, there isn't even agreement, in many cases, on which past precedents are applicable.

This lack of definition sets up a legal confrontation between the incumbents and the proponent of the new technology. Since the deadlines of Section 7 of the *Communications Act* are essentially ignored, as discussed above, this confrontation can go on indefinitely.

Disadvantaged Innovators

Assuming the incumbents have ongoing businesses using the spectrum, and the proponent is funded by venture capital or comparable funding, the regulatory battle could divert a small fraction of the incumbents income and profits, while denying the proponent *any income,* and pushing any potential profits further into the future. And it widens and deepens the cash flow "valley of death"[13] that any entrepreneur faces in developing a new product or service. Sooner or later, it may be just a question of when the proponent will "bleed out" all of its capital, and drop by the wayside. In the case of ultrawideband technology, the three proponents managed to survive the rulemaking process, but the two most active succumbed to bankruptcy within a year. In the recent case of the AWS-3 band, the proponent urged the FCC to give a clear signal five years into its deliberations, and with a telephone call,[14] their proposal was dismissed without ever resolving either the technical or nontechnical issues in their proposal.[15]

In contrast to this endless process for harmful interference deliberations, the FCC has adopted an "informal guideline" for its consideration of corporate mergers, even though no statutory time is required for such deliberations.[16] The Commission's website gives a nominal schedule and makes the following statement about this timeline:

The timeline represents the Commission's goal of completing action on assignment and transfer of control applications (i.e., granting, designating for hearing, or denying) within 180 days of public notice. Routine applications should be decided well within the 180-day mark. More complex applications may take longer. It is the Commission's policy to decide all applications, regardless

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11 FCC, *Notice of Inquiry*, Docket 09-157, August 27, 2009 at para. 34-35

12 47 C.F.R. 1.1204(a)(5)

13 " Into the Valley of Death", http://andrewhargadon.typepad.com/my_weblog/2010/04/into-the-valley-of-death.html

14 *"What's Next for M2Z?"*, *Wireless World Blog*, 9/2/10 (http://www.wirelessweek.com/Blogs/Wireless-Week-Blog/What-s-Next-for-M2Z-/)

15 The nontechnical issues involved a "freemium" plan under which M2Z would receive a license at no auction cost, but with a condition to supply service at a basic rate to anyone seeking it, and then charge for high rates and any special content. The technical issues focused on whether time division duplex (TDD) use of the AWS-3 band was possible, without harmful interference to the lower adjacent AWS-2 band, generally licensed to T-Mobile.

16 *See* http://www.fcc.gov/transaction/timeline.html

of whether they are highlighted on the web page, as expeditiously as possible consistent with the Commission's regulatory responsibilities. Although the Commission will endeavor to meet its 180-day goal in all cases, several factors could cause the Commission's review of a particular application to exceed 180 days. Delay in action beyond the 180-day goal in a particular case is not indicative of how the Commission ultimately will resolve an application.

Furthermore, the website even has a "shot clock" for such applications.[17] In practice, the FCC generally acts on corporate mergers within 12 months of the formal application,consistent with its goal— nominally 180 days-but allows "stopping" the clock. Corporate mergers, like harmful interference determinations, are complex regulatory problems involving balancing of many issues, and often involve thousands of public comments that must be reviewed before making a decision under the APA. But the FCC has determined to resolve harmful interference issues, including issues relating to technical innovation, in a timely way, to help and benefit the economy, as part of its , core Title III Mission.

A sharp contrast exists, then, between actions in complex corporate merger deliberations that lack statutory requirement for any specific schedule for approval, and technical new spectrum technology deliberations involving harmful interference issues that are nominally subject, in many cases, to the Section 7 quantitative time limit that is routinely ignored.

While the corporate entities involved in multibillion dollar mergers certainly incur extra costs while the mergers are pending, entrepreneurial firms seeking approval of innovative wireless technologies in harmful interference determinations are even in more of a life or death battle of beating the clock— before they literally expire.

Governance and Harmful Interference

Under present procedures, the FCC is the final arbiter of harmful interference to nongovernment systems and NTIA for federal government systems. The recent LightSquared/GPS proceeding shows the complexity of situations where FCC-regulated entities are alleged to be an interference risk to NTIA-regulated systems. In practice, the FCC uses notice and comment rulemakings, sometimes supplemented by testing in its own laboratory. In practice NTIA relies almost exclusively on the deliberations of its Interdepartmental Radio Advisory Committee(IRAC),[18] composed of representatives of the major agencies with wireless systems. IRAC operates in a much less transparent fashion than the FCC, in part due to the nature of its intragovernmental role.

In the ongoing GPS/LightSquared deliberations, NTIA has given due deference[19] to the Executive Steering Committee of the Interagency National Executive Committee for Space-Based Positioning, Navigation and Timing (EXCOM), a group which, unlike FCC and NTIA, has no statutory charter in spectrum management. The FCC has not sought input from its Technological Advisory Council[20] and NTIA has not sought input from its Commerce Spectrum Management Advisory Committee[21] in this matter or in any

17 For example, http://www.fcc.gov/transaction/comcast-nbcu.html gives the shot clock for the Comcast/NBC Universal merger

18 http://www.ntia.doc.gov/osmhome/iracdefn.html

19 Letter from NTIA Administrator Strickling to FCC Chairman Genachowski, February 14, 2012 (http://www.ntia.doc.gov/files/ntia/publications/lightsquared_letter_to_chairman_genachowski_-_feb_14_2012.pdf)

20 http://www.fcc.gov/encyclopedia/technological-advisory-council

21 http://www.ntia.doc.gov/category/csmac

other harmful interference matter. By contrast, a detailed study by The Brookings Institution shows how other regulatory agencies use technical advisory committees as part of their deliberations.[22]

Neither FCC, nor NTIA, has sought advice from the National Research Council of the National Academies[23] on a harmful interference issue since the 1970s, although other regulatory agencies with technical jurisdiction[24] seek advice from the National Research Council for complex technical issues in their jurisdiction.

Sometimes harmful interference determinations involve straight forward applications of well-known concepts, while at other times there are novel interference issues. Examples of the later were the Northpoint/MVDDS, ultra-wideband, and AWS-3 controversies. In the Northpoint/MVDDS case, Congress ordered the FCC to get an outside party to evaluate the novel technical issues involved[25] and make a timely recommendation. When selection mechanism in the legislation for the outside party was unworkable, all affected entities agreed that MITRE Corporation was an acceptable contractor.

The resulting MITRE report[26] contained key recommendations for the technical controversy that, in Turn, were generally adopted in the FCC rules[27]. While the FCC had also used a study by the National Academy of Science/National Research Council to set the basis of C band (4/6 GHz) sharing between terrestrial fixed users and satellite users in the 1970s, the use of similar outside studies in FCC spectrum formulation has been exceedingly rare,even though such studies are much more commonly used by other regulatory agencies with technical jurisdiction.

While the transparent notice and comment process provided for in the APA for many public policy determinations has many advantages, its near exclusive use, without any outside independent studies in harmful interference/radio rights issues may be inappropriate, and may result in practice from the lack of funding at the FCC for any alternative. While NTIA has its own well respected laboratory, the Institute for Telecommunications Sciences(ITS), ITS mainly functions as a research contractor for other government agencies, and the NTIA has little funding to support studies at ITS, in support of NTIA's own mission. While the FCC *could* contract with ITS for studies in support of policy deliberations, in practice it does not do so, and probably lacks adequate funding to do so.

Key Technical Issues in Harmful Interference

In this section, we will divide the issue of harmful interference into subproblems that would have to be specified to more fully define the rights of an incumbent, and to determine what is allowed for a new entrant. While some of the subproblems are well understood in some contexts, *e.g.*, broadcast

22 Bruce L. R. Smith, *The Advisers: Scientists in the Policy Process*, The Brookings Institution, 1992

23 http://www.nationalacademies.org/nrc/policies.html

24 http://www8.nationalacademies.org/cp/ReportView.aspx?key=Subject

25 Novel key issues in this controversy included the exact sensitivity of DBS home antennas in operational use in directions other than the intended direction of the satellite system; the impact of heavy rain falls on both the DBS signal path to the receiver; and the MVDDS interference path to the DBS receiver, as well as when or whether infrequent interference became "harmful".

26 MITRE Corp., "Analysis of Potential MVDDS Interference to DBS in the 12.2–12.7 GHz Band" , MTR 01W0000024, April 2001 (http://www.fcc.gov/oet/info/mitrereport/mitrereport_4_01.pdf)

27 47 C. F. R. §§101.1401,1440

televisions to broadcast television interference, technical innovation inevitably results in circumstances no clear precedents or guidance exists for the relevant sub-problems.

The divisions below are not the only ways harmful interference can be divided into several subproblems, and may not include all the issues that are needed, but they show the complexity and multiple facets of the problem.

For topics in which there are applicable ITU-R recommendations,[28] or industry standards,[29] these standards could serve as the starting point for FCC and NTIA clarifications. The prerequisite expertise is available because U.S. experts actively participated in the developing ITU-R recommendations and industry standards; and in most cases, initiated the proceedings and provided technical leadership.

I/S Protection at Receiver

Fortunately, the issue of how much protection a receiver needs has gotten much simpler in the today's digital age. NTIA's survey study found *"(o)ne common feature was that for continuous, long-term interfering signal levels, nearly all established IPC were based on an interference-to-noise power ratio of –6 to –10 dB"*.[30] In the days of analog signals, acceptable I/S ratios varied all over the place, depending on the nature of both the desired and interfering signals. Indeed, analog NTSC TV needed I/S less than -40 dB for some types of interfering signals. Relatively little uncertainty exists for most digital signals, about how much protection they need at the receiver.

For TV broadcasting, there is an ITU-R recommendation on *"protection criteria"*[31] recommending that the total interference at the receiver from all radiations and emissions without a corresponding frequency allocation should not exceed 1% of the total receiving system noise power. Further, the total interference at the receiver, arising from all sources of radio-frequency emissions from radiocommunication services with a corresponding co-primary frequency allocation, should not exceed 10% of the total receiving system noise power. This recommendation should be used as a starting point for determining what clarification on I/S protection is appropriate for TV broadcasting, subject to FCC jurisdiction.

However, for Code-Division Multiple Access (CDMA) systems, such as 2G and 3G cellular, I/S translates directly into cell site capacity— as the cellular industry repeatedly reminded the FCC during the UWB[32] and Interference Temperature[33] rulemakings. This relationship between I/S and capacity is because of the nature of CDMA, where the receiver sees multiple signals overlapping in frequency and sorts them out by processing gain. While ideally the CDMA signals are orthogonal, in reality there is some intersignal leakage in the receiver, and the amount of noise in the receiver limits how many CDMA signal can share the same spectrum block for a base station. In effect, the impact of interference to CDMA systems is very different than the impact to other systems, where it either causes interference or doesn't.

In the UWB proceeding, cellular interests tried to argue for very strict emission limits, and allowable interference from UWB to PCS. Qualcomm said the FCC should define harmful interference as any UWB emission that is greater than 6 dB below the thermal noise floor of the PCS receiver. Motorola based its definition of harmful interference on a PCS receiver, as any signal that causes a 1 dB rise in the receiver

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28 http://www.itu.int/pub/R-REC

29 *e.g.* Telecommunications Industry Association, Interference Criteria for Microwave Systems , 06/94 (http://global.ihs.com/search_res.cfm?RID=TIA&INPUT_DOC_NUMBER=TSB-10

30 NTIA Report 05-432, *op. cit.*, p. ii

31 ITU-R, Recommendation BT.1895, Protection criteria for terrestrial broadcasting systems, 05/2011 (http://www.itu.int/dms_pubrec/itu-r/rec/bt/R-REC-BT.1895-0-201105-I!!PDF-E.pdf)

32 FCC, ET Docket 98-153

33 FCC, ET Docket No. 03-237

thermal noise floor, i.e., resulting from an UWB device that produces signal in the PCS receiver that is 6 dB below the thermal noise floor.[34] The FCC ultimately decided that *"a PCS received signal level of – 96 dBm/1.25 MHz adequately characterizes a low level PCS signal level based on real world applications"* and *"that a S/I of about a 6 dB is required to prevent interference to a PCS system."*[35]

Such decisions for CDMA systems are very difficult, but they are the core of the harmful interference issue. One motivation for the ill-fated *Interference Temperature* rulemaking[36] was to solve this problem in a more general case, so that licensees would have a clear and long-term understanding of how much interference they would have from other signals and natural sources. Ultimately the FCC found that *"(c) ommenting parties generally argued that the interference temperature approach is not a workable concept and would result in increased interference in the frequency bands where it would be used."*[37] Unfortunately, for clarifying harmful interference, one has to make this type of decision one way or another.

I/S Power Flux Density at the Antenna vice I/S Power at the Receiver

In the past, mobile antennas were omnidirectional and other antennas had fixed patterns. In such a scenario, one could reasonably consider the worst case transfer of interference-to-signal (I/S) power flex density ratio at the antenna to I/S power ratio at the receiver to be the same. In the DBS/MVDDS controversy, the DBS antenna was a directional dish antenna, and the interference path involved the back lobe of the victim antenna—for which there was no clear performance standard.

Thus, the I/S power in space at the antenna was inevitably very different than I/S ratio at the receiver input.

Furthermore, MIMO antenna technology is now well established in the commercial world, and will be even more important in the future. MIMO and other adaptive antenna technologies can readily change the I/S ratio at the receiver, by preferentially passing the desired signal and not the interference. Thus, for systems that either use or can be reasonably be expected to use such technology, any harmful interference regime will have to consider how much to budget for I/S reduction attributable to the antenna system.

Propagation Models

Assuming one knows what I/S ratio at the receiver antenna would be acceptable, how would one translate that into acceptable geometries and transmitter power for the new entrant? The answer involves projecting geometry and power with both scenarios and propagation models.

Propagation would be simple if all radio waves behaved like light in a vacuum, with monotonic predictable decrease in field strength, with path length increases. *Some* radio signals are actually rather close to that ideal theory: satellite links at high elevation angles in clear weather and fixed microwave links with high gain antennas in clear weather. However, other radio systems have much more complex

34 FCC, *First Report and Order*, Docket 98-153, (Feb. 14, 2002) at para. 152-161 "UWB R&O"

35 *ibid.*, at para. 162

36 FCC ,*Notice of Inquiry and Notice of Proposed Rulemaking*, Docket 03-237, (Nov. 13, 2003) (http://hraunfoss.fcc.gov/edocs_public/attachmatch/FCC-03-289A1.pdf)

37 FCC, *Order*, Docket 03-237 May 2, 2007 (http://hraunfoss.fcc.gov/edocs_public/attachmatch/FCC-03-289A1.pdf)

propagation and uncertainty resulting from multipath propagation and weather related phenomenon. So, agreeing on a propagation model is a major issue.

The impact of propagation models was shown in the TV White Space Proceeding,[38] where the broadcast interests urged use of the FCC R-6602 model,[39] first published in 1966 and the basis for the FCC's Grade B contours. While this model was a breakthrough for its time and appropriate for the contemporary desktop calculators and paper maps of its time, it does not give the more accurate results possible today, with computer-based models using digital terrain models.[40]

It seems realistic harmful interference determinations will depend on realistic propagation modeling—something that some segments of the wireless community would like to avoid, if traditional models give them a better position.

MCL Vice Stochastic Modeling

The issue of *minimum coupling loss*(MCL) is also key in any harmful interference formulation. In the AWS-3 proceeding, incumbent licensees argued that protection from proposed AWS-3 band TDD emitters to incumbent lower adjacent band FDD downlink mobile receivers must be based on MCL —the worst case scenario. In stochastic modeling, geometries are considered. along with their probabilities yielding a probability estimate for interference. Generally incumbents prefer MCL analysis, as it precludes *any* probability of interference independent of any public interest factors. On the other hand, new entrants would like to show that interference is minimal, and does not meet with the *"seriously degrades, obstructs, or repeatedly interrupts"* part of the harmful interference definition.

At present, the FCC does not have a clear policy on when MCL or stochastic models should be used. This policy absence was a definite factor in the prolongation of the AWS-3 deliberations.

It appears that NTIA insists on MCL for all "safety services," although it is unclear if NTIA considers *all* federal government spectrum use to be a safety service or not.

Uncertainty over harmful interference would decrease, if the NTIA and the FCC would clarify when it is appropriate to use MCL for interference determinations, and what approaches to stochastic modeling are appropriate for harmful interference determinations. It is likely that some agency-funded research might be needed to guide the FCC and the NTIA in the use of stochastic modeling. But ITU-R and

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38 FCC, ET Docket 04-186

39 J. Damelin, W. Daniel, H. Fine and G. Waldom *Development of VHF and UHF Propagation Curves for TV and FM Broadcasting*, FCC, Office of Chief Engineer, Research Div., Report No. R-6602, September 1966 http://www.fcc.gov/oet/info/documents/reports/R-6602.pdf

40 In Docket 98-201, the Commission stated:

"The Commission's traditional predictive methodology for determining a Grade B contour is inappropriate for predicting signal strength at individual locations. Our rules state that this methodology is for three purposes only: (1) estimation of coverage resulting from the selection of a particular transmitter site, (2) problems of coverage related to 47 C.F.R. § 73.3555 (ownership restrictions), and (3) determination of compliance with § 73.685(a) concerning minimum field strength over the principal community. The traditional methodology predicts signal strength on the basis of average terrain elevation along radial lines extending only ten miles from a television station's transmitter. The traditional methodology does not accurately reflect all the topographic differences in a station's transmission area, and explicitly does not account for interference from other signals. <u>These omissions make it an imperfect methodology for predicting whether an individual household can receive an adequate signal.</u> For example, the model may fail to account for terrain features that could block a house's reception."

R&O, Docket 98-201 (February 2, 1999) at para. 67

European regulators using stochastic modeling shows that it can be useful in equitably resolving contentious interference issues.

Minimum Protection Distance

A close relative of the MCL issue is the question of minimum protection distance. Or how physically close a new entrant might be in space to an incumbent's receiver. Since propagated radio signals' strength in a multipath environment is often proportional to $1/d^n$, where d is distance from transmitter to receiver and $2<n<4$, simple math shows that as dÕ0 the received power becomes infinite! In the real world, there are either minimal physically possible distances, or minimum distances beneath which a user is causing interference to only himself.

The Commission's landmark 1979 decision on regulations of unintentional emissions from PCs and other "digital devices" stated: *"We are assuming that the home computing device is at least 10 meters from the receiver. The separation distance is a basic parameter in computing tolerable levels of signal that may be radiated by a computer."* And then picked an emission level that would not cause interference to TV receivers at 10m distance, even though industry recommended a 30m minimum protection distance.[41] In the UWB case, the FCC limits were based on an assumption of 2m minimum separation distance between portable UWB transmitters and GPS receivers,[42] and 1.8m away from PCS receivers.[43]

In the AWS-3 case, cellular interests argued that minimum separation (and MCL determination of its impact) should be 0.5m, based on a scenario where two cell phone users are in adjacent seats on a bus or train and hold their cell phones to opposite ears so that the interphone spacing is small. As this proceeding ultimately was dismissed with an undocumented phone call, no actual determination of what the minimum separation distance should have been was mandated.

Acceptable Interference Statistics

What does the harmful interference definition mean with respect to interference that *"seriously degrades, obstructs, or repeatedly interrupts?"* This question has rarely come up in FCC deliberations, but was a key issue in the MVDDS/Northpoint proceeding. DBS satellite systems have natural outages that result from excessive desired path lost during heavy rain. For typical home antennas in the Washington, D.C. area, this comes to about 120 minutes/year. The DBS operators argued that *any* increase in outages over this naturally occurring level would be harmful interference. The Commission ultimately decided that *de minimis* increases would not be harmful, and based in technical rules on an objective of increasing rain related outages by no more than 10%[44] over the naturally occurring outages—actually the naturally occurring outages predicted by a standard ITU-R model.[45]

The Commission tried hard to limit this outage increase precedent to only the MVDDS issue at hand; this point is key in harmful interference. Is interference, caused by any new entrant that is *de minimis* with naturally occurring outages in space or time, really "harmful"? Most incumbents want to believe that they have perfect coverage within their nominal service area. But in most cases, they *don't*— due to

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41 FCC, *Report and Order,* Docket 20780, (Sept. 18, 1979), 79 F.C.C.2d 28, at para. 53

42 FCC, *UWB R&O* at para. 107

43 *ibid.*, at para. 162

44 FCC , *Memorandum Opinion and Order and 2nd Report and Order*, Docket 98-206, April 11, 2002 at p. 29

45 In reality, heavy rain statistics vary greatly from year to year. Also the ITU-R model only has data for a grid points about 60 miles apart and uses linear interpolation between data points. As a result, actual rain rates and the resulting satellite outages during a given year at a given place may vary widely from the predicted data. The real impact of a 10% increase would be impossible to differentiate over the base case.

factors such as multipath propagation, terrain shielding, limits of real receiver with respect to dynamic range and selectivity, and weather-related phenomena.

In the case of the low-power Frequency Modulation (FM) rulemaking, incumbent broadcasters pointed out expected coverage losses near low-power entrants on adjacent frequencies, when typical receivers' performances were considered. However, they made no comparisons of the magnitude of these outages with the base case: existing outages with typical consumer FM broadcast receivers near other FM stations.

In considering a harmful interference regime, the NTIA and the FCC should consider the realistic coverage and reliability of a nonsafety service incumbent, along with an estimate for its improvement with new technology, as the base case to compare the impact of any loss resulting from a new service. This comparison would be a useful generalization of the MVDDS 10% increase case, with the percentage change in allowed outages considered in the context of the incumbent service and the new service.

Possible Procedural Approaches for Clarifying Harmful Interference

It is doubtful the FCC could develop and adopt a realistic and constructive harmful interference proposal using only the standards notice and comment rulemaking procedure normally used, although such a rulemaking will almost certainly be necessary in the final stages of clarification. Similarly, the normal procedures of the NTIA and IRAC under present legislation and practices focus so much on the rights of the individual member agencies of IRAC, that the overall "public interest" of the *Communications Act* may not get adequate attention. Then, it becomes necessary to develop a compromise solution that advances the public interest—unlikely in the present FCC and NTIA structure(s).

It is interesting to look at spectrum management in Europe, where there are two separate spectrum management entities: the traditional Conference of Postal and Telecommunications Administrations (CEPT)[46] that developed from the classic monopoly PTTs; and the newer Radio Spectrum Policy Group/RSPG[47], a European Commission organization. In the CEPT, as in the FCC and NTIA, the incumbents have significant influence over the direction of policy, particularly with respect to protection of incumbents from either interference or competition. By contrast, RSPG is more focused on contributing to overall European economic and social goals, and less concerned about the near-term impact on incumbents.

In the 1970s, when the FCC faced challenging paradigm shifts with respect to both satellite/terrestrial sharing of C band and telephone interconnection/Carterphone policies[48], it turned to the well-respected National Academy of Sciences/National Research Council to develop policy proposals for its consideration; and based the ultimate rules in Part 25 and Part 68, in great part, on those recommendations. This type of bold step may be necessary to break from the past deadlock. Alternatives might include the President appointing a "Blue Ribbon Commission," to consider spectrum reform, or using a subcommittee of the President's Council of Advisors on Science and Technology (PCAST) to formulate basic recommendations.

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46 http://www.cept.org/

47 http://rspg.groups.eu.int/

48 Panel on Common Carrier/User Interconnections; Computer Science Engineering Board; National Academy of Sciences, *A Technical Analysis of the Common Carrier/User Interconnections Area,* June 1970, (http://www.nap.edu/catalog.php?record_id=13320)

Conclusions

For at least two decades, the United States has had a deregulatory policy for most wireless technology. This policy has brought us leadership in areas such as Wi-Fi and CDMA. But wireless innovation is impeded by excessive regulatory uncertainty, resulting from the vague definition of "harmful interference," and the inability to resolve related novel questions in a timely and transparent manner.

By contrast, our foreign competitors operate in spectrum policy systems that are a form of "state capitalism," and where spectrum policy is a key aspect of national industrial policy. The consensus nature of these processes inhibits wireless "disruptive innovation," but eliminates almost all regulatory risk. If the United States cannot make its deregulatory spectrum system function reasonably for innovative technologies, the private sector funding for innovative research may well dry up, as capital sources seek non-U.S. nations with less regulated fields, or with more transparent regulation, e.g., FDA-regulated pharmaceuticals and medical technology.

This White Paper outlines the various technical subproblems involved in harmful interference determinations. While an unambiguous definition of harmful interference is almost certainly an unachievable goal, progress in clarifying some, or all of the subproblems, would improve transparency in harmful interference deliberations. The clarifications need not be an explicit statement in each case, but could be a clear list of alternative approaches and factors used to determine when each alternative should be used.

The process used at the FCC and the NTIA to make harmful interference determinations, including the role of technical advisory committees and outside experts, should also be clarified.

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